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AN ANALYSIS OF CONCRETE FROM DETERIORATING PILES AT THE RODNEY TERMINAL, ST. JOHN, NEW BRUNSWICK

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by

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ABSTRACT

Deterioration of concrete piles at the Rodney marine terminal at St. John, N.B. invoked a study to determine the cause of destruction. Petrographic studies of fragments of the piles at this laboratory revealed that the cement-aggregate bonding is weak and the matrix pores and capillaries are mostly filled with ettringite, and expansive reaction product, and secondary calcite. The concrete appears to have been permeable to the marine solutions, and the reactions produced deleterious stresses. Fractures apparently related to the strengthening steel accelerated the access of solutions.

ANALYSE DU BÉTON PROVENANT DE PILOTIS EN ÉTAT DE DÉTÉRIORATION DU TERMINAL EN EAU PROFONDE DE RODNEY, ST.-JEAN (NOUVEAU-BRUNSWICK)

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RÉSUMÉ

La détérioration des pilotis en béton du terminal en eau profonde de St.-Jean (N.-B.), a donné lieu à une étude en vue de déterminer les causes de la destruction. Des études pétrographiques des débris de pilotis effectuées à ce laboratoire ont révélé que le liant ciment-aggrégat est faible et que les pores et capillaires de la matrice sont principalement remplis d'ettringite, un réactif dilatable, et de calcite secondaire. Le béton semble avoir été perméable aux solutions de sel marin et les réactions ont produit des contraintes délétères. Il semble que les fissures qui se sont produites dans le béton soient reliées à la consolidation de l'acier et aient accéléré la pénétration des solutions.

INTRODUCTION

Deteriorated concrete piles that have been in place for only a few years at the Rodney Terminal in St. John, N.B. have been examined carefully to determine the possible cause of damage. Field studies have been made and thin sections and polished surfaces were prepared to permit examination and analysis of the constituents.

RESULTS

EXTENT OF DAMAGE

The piles were pre-cast, steel-reinforced cylindrical shells, most of which had been filled with concrete after emplacement. An on-site inspection of damaged piles and deck concrete had been made at the terminal site in 1977 by W.G. Corley and his associates of the Portland Cement Association (1). He reported that a few piles had contained cracks prior to their being driven, cracks often developed during driving, and cracking and concrete corrosion appeared to be associated mostly with thinly embedded longitudinal reinforcement bars. However, the degree of alteration of the concrete is high, which suggests that reactions within the paste were excessive.

PETROGRAPHY OF SELECTED SPECIMENS

Two samples from pile shells, labelled 40M and 20K, were received for examination in this laboratory. The specimens were similar, except that the original concrete in the 20K sample had apparently been coated with a fine grained concrete mortar having a flexible matrix that has resisted weathering.

The coarse aggregate in the pile shells is heterogeneous, consisting predominantly of recrystallized dolostone and limestone, granites of different composition, lesser amounts of volcanic rock, minor sandstone and scarce siltstone. The particles are angular to rounded, suggesting that the material was partly a crushed gravel; the carbonate aggregate are mostly angular. Fine aggregate consists mostly of rounded to subangular particles

of granitic rock, quartz, feldspar, and minor carbonates. The aggregate in the overlay mortar is principally rounded granitic sand, rather similar in composition to the fine aggregate of the primary concrete.

Deterioration of the primary concrete consists of an apparent loss of paste-aggregate bond strength, formation of secondary carbonate and other leach products, and development of random fractures through the concrete, mostly following grain boundaries. Aggregates and fractures are often coated by the alteration products, and the pores in the paste have been partially to completely filled with them (Fig. 1); a high permeability of paste, particularly along aggregate boundaries, is indicated. There are no apparent reaction rims on aggregates other than on original gravel particle surfaces.

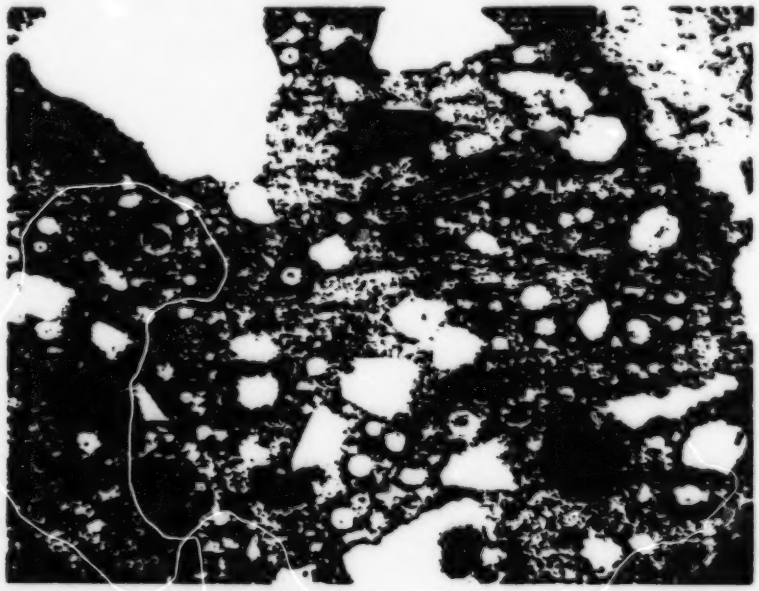

Fig. 1. Photomicrograph of polished surface of Rodney Terminal concrete pile shell. Note that original air voids (circular) are partly to completely filled with a reaction product that was identified as ettringite. Magnification X30.

X-ray diffraction analyses were made of secondary products selected from aggregate-paste interfaces and within entrained air voids. The predominant phases are calcite and ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$; only ettringite is abundant in closed internal pores. Evidently sulphatic solutions migrating through the paste reacted with aluminous cement materials.

CONCLUSIONS

The fragments of primary concrete examined do not appear to have suffered alkali-aggregate reaction. Aggregate-paste bonds are weak, fracturing is widespread and leach products are common, but there are no alkali-silica reaction rims on aggregate, nor are typical siliceous products formed by A-A reactions observed in pores or fractures. A compositionally different overlay concrete has not deteriorated; its paste is not reactive.

The reaction products present in the primary concrete are principally calcite, the normal phase resulting from carbonation of $Ca(OH)_2$, and ettringite, an expansive and often destructive phase that results from the reaction of sulphatic marine solutions with aluminous cement hydrates (2). The concrete paste was obviously permeable to those solutions, and the secondary ettringite has been deposited in pore spaces and along fractures. The porosity of the matrix has thereby been reduced greatly, and the cement bonds were probably weakened.

According to the earlier field study of the piles (1; App.B) longitudinal fractures related to the reinforcement steel in the relatively thin shells were common, which suggests that design or concreting procedure may have been casual. The fractures appeared to have developed after most of the concrete strength had been attained, so the primary cause of fracturing was in doubt; driving of the piles may have been largely responsible. Deterioration of the paste would be accelerated by easier access of marine solutions along such fractures.

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